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Request for grant of a patent

The Patent Office

Cardiff Road
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07 APR 2000

1.	Your reference	DL-P543
2.	Patent application number	0008469.9
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	DISCREET LOGIC INC 10 Duke Street Montreal Quebec Canada H3C 2L7
	Patents ADP number *(if you know it)*	7 72
	If the applicant is a corporate body, give the country/state of its incorporation	Quebec, Canada
4.	Title of the invention	Processing Image Data
5.	Name of your agent	ATKINSON BURRINGTON
	"Address for service" in the United Kingdom to which all correspondence should be sent	The Technology Park Shirland Lane Sheffield S9 3PA GB
	Telephone No:	0114 242 4581
	Patents ADP number	7807043001

		Country	Priority application number *(if you know it)*	Date of filing *(day/month/year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	N/A	N/A	N/A

		Number of earlier application	Date of filing (day/month/year)
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	N/A	N/A

8.	Is a statement of inventorship and of right to grant of a patent required in support of this request?	Yes

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	16
Claim(s)	08
Abstract	01
Drawings	15 4 15 14

10. If you are also filing any of the following, state how many against each item.

Priority documents	N/A
Translations of priority documents	N/A
Statement of inventorship and right to grant of a patent (*Patents Form 7/77*)	None
Request for preliminary examination and search (*Patents Form 9/77*)	None
Request for substantive examination (*Patents Form 10/77*)	None
Any other documents (*Please specify*)	

11. I/We request the grant of a patent on the basis of this application.

Signature

Date **Thursday, 06 April 2000**

12. Name and daytime telephone number of person to contact in the United Kingdom

RALPH ATKINSON CPA
0114 242 4581

Processing Image Data

Field of the Invention

The present invention relates to apparatus for processing image data, a method of processing image data and a computer-readable medium.

Introduction to the Invention

The digitisation of image processing has enabled many new image manipulation techniques to be developed. Available digital processing effects include a process of colour warping, in which colour attributes of an image, or area of an image, can be modified in some way. Common uses for such a technique are compensation for camera or film colour distortions and special effects.

Many image processing systems provide control over colour through the use of gamma correction curves. A gamma correction curve define transfer functions that are applied to red, green and blue image data values, in such a way that a colour transformation may occur. However, manipulation of such curves to produce satisfactory results is extremely difficult. In the case of creating special effects, the lack of intuitive feel of such an approach makes achieving useful results extremely difficult.

From a mathematical perspective, many systems provide colour transformations defined in terms of matrices. Matrices may be used to define arbitrary transformations in colour space, just as they are used in the more familiar world of computer modelling and computer-aided design. However, although such techniques theoretically provide an enhanced level of control over colour space, and have the potential to facilitate useful colour warping tools, the lack of an intuitive relation between the mathematics and the effect

upon the colours of an image makes these techniques difficult to use.

Summary of the Invention

According to an aspect of the present invention, there is provided apparatus for processing image data, comprising storing means for storing instructions, memory means for storing said instructions during execution and for storing image data, processing means for performing image processing in which said image data is processed to modify colour values, and display means for facilitating user interaction with said image processing, wherein said processing means is configured such that, in response to said instructions, said image data is processed by the steps of: identifying a colour vector and a luminance range for said colour vector; defining a colour vector function in response to said identification, in which said colour vector is a function of luminance; processing source image data to identify luminance values; and modifying colours in response to said luminance values with reference to said colour vector function.

Brief Description of the Drawings

Figure 1 shows an image processing system including a computer and a monitor;

Figure 2 details components of the computer shown in *Figure 1*, including a main memory;

Figure 3 details user operations performed on the image processing system shown in *Figure 1*, including processing images;

Figure 4 details the contents of the main memory shown in *Figure 2* as they would appear during the image processing shown in *Figure 3*;

Figure 5 details processes performed during image processing shown

in *Figure 3*, including a colour warper;

Figure 6 details the colour warper process shown in *Figure 5*, and summarises the invention, including a colour vector graph and steps of defining a colour vector function, updating a colour vector LUT and processing a source image;

Figure 7 details the user interface presented to the user on the monitor shown in *Figure 1* during operation of the colour warper process shown in *Figure 5*;

Figure 8 details examples of the colour vector graph shown in *Figure 6*;

Figure 9 details the step of defining a colour vector function shown in *Figure 6*, including steps of translating a colour vector and modifying curves;

Figures 10 and *11* detail calculations involved in the step of translating a colour vector shown in *Figure 9*;

Figure 12 details the step of modifying curves shown in *Figure 9*;

Figure 13 details the step of updating a colour vector LUT shown in *Figure 6*;

Figure 14 details colour space relationships used by the invention; and

Figure 15 details the step of processing a source image shown in *Figure 6*.

Detailed Description of The Preferred Embodiment

The invention will now be described by way of example only with reference to the accompanying drawings.

A system for the processing of image data is illustrated in *Figure 1*. A digital tape player **101** plays and records digital tapes having a high data capacity suitable for storing many frames of high definition image data. In

preparation for image processing, images for a film clip are transferred from a tape in the tape player **101** to a frame store **102**. The frame store **102** comprises several high capacity hard disk drives, arranged to supply and store image data in parallel across many individual drives at once. The hard disk drives are configured as a redundant array of inexpensive disks (RAID). Using the frame store **102**, it is possible to play back and record high resolution film images at any location in a clip without having to wait for a tape wind mechanism to reach the required frame. Furthermore the frame store facilitates real time play and record of image data, when the amount of processing being performed is minimal, for example when previewing a stored clip.

A computer **103** facilitates the transfer of image data between the tape player **101** and the frame store **102**. The computer **103** also facilitates the modification, processing and adjustment of image data to form an output clip that will eventually be stored onto digital tape. The computer is a Silicon Graphics Octane (TM). Images are previewed on a monitor **104** on which is also displayed a graphical user interface (GUI) to provide the user with several controls and interfaces for controlling the manipulation of image data. When processing image data, the user interacts with images and the graphical user interface displayed on the monitor **104** via a graphics tablet **105**. For alphanumeric input, there is provided a keyboard **106**, although facilities may be provided via the graphical user interface to facilitate occasional text input using the graphics tablet **105**.

In addition to receiving image data from the tape player **101** and the frame store **102**, the computer **103** may receive image and or other data over a network. The image processing system shown in *Figure 1* facilitates the manipulation of image data by a digital artist in order to achieve high

quality special effects and processing of image data.

In a typical application, film clips are digitised and stored on digital tape for transfer to the system shown in *Figure 1*. The film clips include several camera shots that are to be combined into the same scene. It is the task of the user or digital artist to combine and process this source image data into a single output clip that will be stored back onto tape for later transfer to film or video. Typical examples of this type of scene are where real images shot by a film camera are to be combined with artificially generated images and backgrounds, including scenes where actors are to be placed in computer-generated environments.

The computer **103** shown in *Figure 1* is detailed in *Figure 2*. Two MIPS R12000 central processing units (CPUs) **201** and **202** are configured to process instructions and data in parallel. Primary cache facilities are provided within each of the processors **201** and **202** in the form of a separate instruction and data cache. Both processors **201** and **202** are equipped with a one megabyte secondary cache **203** and **204**. The CPUs **201** and **202** are connected via a memory controller to a switch **206** and a main memory **207**. The main memory **207** comprises two gigabytes of dynamic RAM.

The switch **206** enables up to seven different non-blocking connections to be made between connected circuits. A graphics card **208** receives instructions from a CPUs **201** or **202** in order to render image data and graphical user interface components on the monitor **104**. A high bandwidth SCSI bridge **209** facilitates high bandwidth communications to be made with the digital tape player **101** and the frame store **102**. An I/O bridge **210** provides input output interface circuitry for peripherals, including the graphics tablet **105**, the keyboard **106** and a network. A second SCSI

bridge **211** provides interface connections with an internal hard disk drive **212**. This has a capacity of thirteen gigabytes. The second SCSI bridge **211** also provides connections to a CDROM drive **213**, from which instructions for the central processing units **201** and **202** may be installed onto the hard disk **212**.

Steps performed by the user when operating the image processing system shown in *Figure 1* are detailed in *Figure 3*. At step **301** the user switches on the computer **103** and logs on to their user account. If necessary, the user proceeds to step **302** in order to install Flame instructions onto the computer's hard disk **212**. Instructions may be provided on a CDROM **303** via the CDROM drive **213**, or over a network. Thereafter, control is directed to step **304**, whereafter the instructions are executed by the CPUs **201** and **202**.

If starting on a new job, it will be necessary to obtain image data from film or video clips stored on digital tapes. This is done at step **305**, where input clips are transferred from the tape player **101** to the digital frame store **102**. Once a finished clip has been generated from the input clips, this is exported to tape at step **306**. Alternative forms of import and export of image data may be performed as necessary, including transfer of image data over a network, transfer of image data from CDROM or transfer of data directly from a camera that may be connected to the input of a suitably equipped graphics card **208**. Once finished using the image processing system, at step **307** the user logs off from their account and the computer and other equipment are switched off if necessary.

The contents of the main memory **207** shown in *Figure 2*, during image processing **304**, are detailed in *Figure 4*. An operating system **401** provides common instructions required for applications running on the

computer **103**. A suitable operating system is the Irix (TM) operating system available from Silicon Graphics.

In the present embodiment, the main memory includes Flame instructions **402** for image processing. The present applicant has image processing applications that include Flame (TM), and the word Flame will henceforward refer to an improved version of Flame, operating in accordance with the present invention. Flame instructions **402** include colour warper instructions **403**. The instructions **402** and **403** may originate from a CDROM **303** or over a network connection, such as an Internet connection.

Main memory **207** further comprises a workspace **404**, used for temporary storage of variables and other data during execution of instructions **401**, **402** and **403** by the processors **201** and **202**. The main memory also includes areas for source image data **405**, a colour vector function **406**, a colour vector LUT 407 and output image data **408**.

Image processing **304** shown in *Figure 3*, facilitated by instructions **402** and **403**, is detailed in *Figure 5*. At step **501** the user initiates operations to import clips of image data. A clip comprises sequential image frames that may originate from a variety of sources, such as video or film. Each frame may comprise several megabytes of image data, depending upon the source and data format. The import operation results in a transfer of image data from a source medium, such as a digital tape on digital tape player **101**, to the frame store **102**.

At step **502**, image processing other than colour warping is performed. Many operations may be performed at step **502**, including effects such as colour keying, image distortion, motion blur, and so on.

Colour warping is a process in which a general shift in colour is

applied to an image. Known systems provide colour warping using gamma curves for red, green and blue colour components. While these curves provide comprehensive control of colour, the relation between the user's interaction with such curves and the resulting change in colour in an output image is non-intuitive.

At step **503** an image is identified for colour warping, and the colour vector function **406** is initialised so as to have no effect. At step **504** colour warping is performed in accordance with the present invention, and in accordance with operations performed by the processors **201** and **202** in response to the colour warping instructions **403**. At step **505** a question is asked as to whether the colour warping result is satisfactory. If not, control is directed to step **504**, and the colour warp effect is modified. Eventually, after several iterations, the resulting output image will have a satisfactory appearance. Thereafter, control is directed to step **506**, where a question is asked as to whether another image requires colour warping. If so, control is directed to step **503**. Alternatively, definitions of colour warping for an image or plurality of images is complete, and control is directed to step **507**.

At step **507** a question is asked as to whether the colour warping defined at step **504** should be animated. Colour warping at different frames may be used to control an interpolated colour warp for intermediate frames. This enables a gradually changing colour warp to be applied over the duration of a clip. If an animated colour warp is required, control is directed to step **508**, where intermediate frames in the clip have their images modified automatically, without the need to repeat step **504** for each intermediate frame on an individual basis.

At step **509** a question is asked as to whether more image processing is required, for example, for other clips. If so, control is directed

to step **502**. Alternatively image processing is complete, and the resulting output clips may be exported to tape or other medium, at step **510**.

Colour warping **504**, as performed in accordance with the present invention, is summarised in *Figure 6*. A colour vector function is defined at step **601**. The colour vector function defines colour vectors as a continuous function of luminance. In the preferred embodiment, this continuous function is defined by nine discreet data points that can be joined by a bspline curve when intermediate data values are required. The colour vector function is represented at the top of *Figure 6* in the form of a colour vector graph **611** that is presented to the user during the colour warping.

The colour vector graph **611** has three components, one each for red **612**, green **613** and blue **614**. These components can be made to vary in their proportions as a function of luminance **615**. For any given luminance Y', the red, green and blue values add up to give a total of one. At either end of the graph **611**, the colour vector is zero, and the three curves converge to a common value of one third. The vertical axis of the graph is scaled in such a way that one third appears as half the maximum colour displacement.

A minimum luminance **616** and a maximum luminance **617** define a range of luminance over which a colour vector will be added to the colour vector function **406** that is already displayed in the graph **611**. The colour vector is defined by user manipulation of a graphical user interface widget in the form of a trackball **618**. The trackball has colour dimensions Pb and Pr of the Y'PbPr colour space. The user can drag the centre **619** of the trackball in any direction **620**. The magnitude of this movement defines the amplitude of the colour vector that is being added to the graph. The direction of this movement defines the colour. As soon as the drag

operation is finished, the trackball **618** reverts to its central state, thereby enabling the user to accumulate many such vector inputs. By also modifying the luminance range using the markers **616** and **617**, the user is quickly able to build up a complex colour vector function **406**.

The colour vector function **406** defined at step **601** is defined as a set of nine points for each of red, green and blue curves shown in the graph. At step **602** the colour vector function **406** is used to create a colour vector look-up table **407** (LUT). The use of a look-up table **407** enables subsequent image processing to take place with minimal computation requirements. At step **603** the source image **405** is processed with reference to the LUT **407** created at step **602**, resulting in the generation of an output image **408**. Finally, at step **604**, the output image is displayed on the monitor **104**, so that the user can determine whether or not the result is satisfactory, and what modifications might be required in the next iteration of the colour warping steps **601** to **604**.

The interface presented to the user of the monitor **104** when performing colour warping **504**, is shown in *Figure 7*. The source and output images **405** and **408** are displayed in the top half of the screen. Transport controls **701** and a timeline **702** enable a user to select individual frames from a clip, or to preview or render a sequence of frames or an entire clip. Other controls are provided for the control of colour warp animation and the saving and loading of settings. The colour vector graph **611** and the trackball **618** are at the bottom of the screen. The luminance markers **616** and **617**, in combination with the trackball **618**, facilitate quick definition of a range of luminance values and a colour vector to be added to the existing colour vector function over the identified range **616**, **617** of luminance values.

Examples of the types of colour vector functions that can be achieved are shown in their graph form **611** in *Figure 8*. With the range markers **616**, **617** set to luminance values of zero and one respectively, colour vectors defined by user manipulation of the trackball **618** cause a general change to the red, green and blue colour curves, as shown at **801**. With the maximum marker **617** moved to a luminance of one quarter, changes can then be made to the curves over a selected small range of luminance, with no changes to the curves outside this range, as shown at **802**. After multiple iterations of range selection and colour vector addition, complex curves can be created, as shown at **803**. The level of complexity shown at **803**, however, can be built up extremely quickly due to the nature of the interface provided.

The step of defining a colour vector function, shown at **601** in *Figure 6*, is detailed in *Figure 9*. At step **901** the user identifies a luminance range and a colour vector for that range, using the range markers **616**, **617** and the trackball **618**. In order to update the colour vector function **406** and also the curves of the graph **611**, it is necessary to perform processing that combines the user's identified luminance range **616**, **617** and colour vector **620** with the existing colour vector function. These calculations are performed at steps **902**, **903** and **904**.

At step **904** the colour vector, expressed as Pb and Pr co-ordinates, is translated into barycentric co-ordinates for red, green and blue. These barycentric co-ordinates represent the difference to be added to the red, green and blue curves of the existing colour vector function. At step **903** these red, green and blue increments are applied proportionately to existing red, green and blue curves over the selected range of luminance values. Function characteristics outside the selected range are not affected by

changes made inside the selected range. Furthermore, the colour vector defined by the trackball movement has maximum effect in the centre of the identified range, and practically no effect at its minimum **616** and maximum **617** points.

The curve data that is modified comprises nine data points for each colour. Each point has a value, and the collection of twenty-seven data values defines the colour vector function. For subsequent processing, these curves require continuous representation. At step **904**, bsplines are created to represent the newly updated red, green and blue curves. Finally, at step **905**, the colour vector graph **611** is updated so that the user has an immediate view of the effect of his or her actions on the graph, as well as on the output image. Steps **901** to **905** all take place as soon as the user makes a modification using the trackball **618**.

The translation of a colour vector into barycentric co-ordinates, shown at step **902** in *Figure 9*, requires calculations illustrated in *Figure 10*. At **1001** the trackball **618** is shown in its neutral condition, with its centre mark **619** located in the middle of the PbPr colour plane. The user drags the trackball towards the lower left, resulting in a displacement of the centre **619** as shown at **1002**. This displacement has PbPr co-ordinates that require definition in red, green and blue terms.

Locations of red, green and blue are shown in relation to the PbPr colour plane at **1003**. The red, green and blue points are joined by lines to form a triangle. This triangle is divided into three by lines drawn from red, green and blue points to the centre at PbPr = (0,0). In *Figure 10*, each triangle is named R, G or B according to its opposite colour. If the centre is dragged towards green, as shown at **1004**, triangle G increases in area. If the initial areas of the triangles are all equal, the change in areas defines

the differences that will be applied to red, green and blue curves of the colour vector function. Because the area of the red, green, blue triangle is fixed, the R, G and B areas represent varying colour proportions whose overall sum does not change, these areas may therefore be considered as being barycentric co-ordinates.

Calculations for obtaining barycentric co-ordinates in accordance with the processes illustrated in *Figure 10*, are detailed in *Figure 11*. For the purposes of *Figure 11*, the equations shown relate to points R, G and B at the red, green and blue points of PbPr colour plane, and X is the centre of that plane at PbPr = (0,0). At step **1101** the area of triangle RGB is calculated. At step **1102** a variable REDFACTOR is calculated by dividing the area of triangle XGB by the area of triangle RGB calculated at step **1101**. A value of one third is then subtracted from the result of this division. A similar process is repeated for the green and blue factors at steps **1103** and **1104**.

The proportionate modification of red, green and blue curves, shown at step **903** in *Figure 9*, is detailed in *Figure 12*. Each curve is defined by a data value at each of nine control points. At step **1201** the first or next of the nine control points is selected. At step **1202** a variable Y is given the value of luminance for that control point. The first control point will have a Y value of zero, the last control point will have a Y value of one. At step **1203** a question is asked as to whether Y is in the range defined by the minimum and maximum luminance markers **616** and **617**. If not, not adjustments are required for this control point, and control is directed to step **1208**. Alternatively, control is directed to step **1204**, where a gain value is calculated. This has the effect of defining a gain value of one if the control point is at the very centre of the identified luminance range **616**, **617**, and

this varies in a sine curve down to zero at the limits of the identified luminance range **616**, **617**.

At step **1205** the current value REDCTRL for the red control point is modified by multiplying the REDFACTOR calculated at step **1102** in *Figure 11* by GAIN calculated at step **1204**. A similar process is repeated for GREENCTRL and BLUECTRL at steps **1206** and **1207**. At step **1208** a question is asked as to whether another of the nine control points requires consideration. If so, control is directed to step **1201**. Alternatively, all control points for the red, green and blue curves have been updated.

Updating the colour vector LUT **407**, performed at step **602** in *Figure 6*, is detailed in *Figure 13*. The steps shown in *Figure 13* relate to an embodiment in which luminance values are processed as integers in the range zero to **255**. In this embodiment, an LUT having **256** entries is used. However, in an alternative embodiment, where 4096 different luminance levels are used to represent luminance from zero to one, a LUT **407** having 4096 entries can be used. At step **1301** the first or next address value, N, from zero to two hundred and fifty-five, is selected. At step **1302** a luminance value Y is calculated, being equal to N/255. At step **1303** each of the red, green and blue bsplines created at step **904** in *Figure 9* is evaluated to determine a barycentric co-ordinate for luminance Y. This may be considered with reference to the graph **611**. Two hundred and fifty-six vertical slices are considered, and at each of these a value for red, green and blue is calculated from the respective bspline. These are assigned to variables U, V and W respectively.

At step **1304**, Pb and Pr co-ordinates are obtained from the barycentric co-ordinates U, V and W. This may be considered as the inverse of the process described in *Figures 10* and *11*. At step **1305**, the

luminance Y' of the PbPr colour plane is set to zero, and the Y'PbPr co-ordinates are then translated into RGB co-ordinates by means of a transformation matrix that converts between these colour spaces. The RGB values that are generated range from negative to positive. If the RGB values are all zero, this corresponds to no change in colour. The RGB values may be considered as representing a vector that, if added to an RGB pixel of the appropriate luminance, results in the appropriate level of colour warp as defined by the user.

At step **1306** the LUT **407** is updated. The LUT comprises three parts, one table each for red, green and blue values. Each of these tables is addressed by the value N, selected at step **1301**, and is written with the value calculated at step **1305** for the respective colour. At step **1307** a question is asked as to whether another address needs to be considered. If so, control is directed to step **1301**. Alternatively, this completes the LUT update process **602**.

Figure 14 details the relationship between RGB and Y'PbPr colour spaces. Pixel data for images **405** and **408** is stored in RGB form, with each pixel being defined by an intensity value for red, green and blue components. In Y'PbPr colour space, Y' is a dimension of pure luminance, that may be expressed as a range of fractional values from zero to one. Pb and Pr are pure colour dimensions, with Pb being closely related to the blue of RGB, and Pr being closely related to green. Pb and Pr range across negative and positive values, and these may be considered as varying from minus one to plus one. However, these values are arbitrary and depend upon implementation.

Y'PbPr colour space may be considered as having a cylindrical shape with a central axis Y', that is a vector extending out from the origin of

RGB colour space, as shown at **1401**. Conversion between these colour spaces may be achieved by a matrix, and the parameters required for a transformation from RGB to Y'PbPr are detailed at **1402**. Transformation from RGB to Y'PbPr may be assigned to a matrix A. The inverse of A, A^{-1}, provides transformation from Y'PbPr to RGB. There is an intuitive relationship between these colour spaces for colours of pure black and pure white, as shown at the bottom of *Figure 14*. Matrix A^{-1} is used in step **1305** to convert from Y'PbPr colour space to RGB colour space.

Processing the source image, performed at step **603** and shown in *Figure 6*, is detailed in *Figure 15*. At step **1501** the first or next source image pixel is selected. This pixel has values (Rs,Gs,Bs). At step **1502** the luminance of this pixel is calculated by applying the equation for Y' shown at **1402** in *Figure 14*. At step **1503** an address value N is calculated, and at step **1504** this address value is used to access a data value in each of the red, green and blue tables of the LUT **407**. These values are added to Rs, Gs and Bs to obtain the RGB data for the output image pixel. At step **1505** a question is asked as to whether another pixel requires processing. If so, control is directed to step **1501**. Alternatively, all source image pixels have been processed, and the result is a new output image **408**.

Claims

1. Apparatus for processing image data comprising storage means for storing instructions, memory means for storing said instructions during execution and for storing image data, processing means for performing image processing in which said image data is processed to modify colour values, and display means for facilitating user interaction with said image processing, wherein

said processing means is configured such that, in response to said instructions, said image data is processed by the steps of:

identifying a colour vector and a luminance range for said colour vector;

defining a colour vector function in response to said identification, in which said colour vector is a function of luminance;

processing source image data to identify luminance values; and

modifying colours in response to said luminance values with reference to said colour vector function.

2. Apparatus according to claim **1**, wherein said colour vector function is defined by points on curves.

3. Apparatus according to claim **1**, wherein said colour vector function is animated.

4. Apparatus according to claim **1**, wherein said colour vector function is defined by applying said identified colour vector to a previously defined colour vector function.

5. Apparatus according to claim **1**, wherein said colour vector function is expressed as a look up table addressable by luminance values of image colour data.

6. Apparatus according to claim **1**, wherein said colour vector function defines red, green and blue displacements with reference to barycentric co-ordinates.

7. Apparatus according to claim **1**, wherein a user performs operations to control said image processing with reference to a graphical user interface presented on a monitor, said interface including a plurality of widgets for facilitating user communication with said processes for modifying colour values.

8. Apparatus according to claim **7**, wherein said identification of a colour vector is performed with reference to a user input of co-ordinates from a two-dimensional trackball widget, in which the dimensions controllable from said trackball are dimensions of pure colour.

9. Apparatus according to claim **7**, wherein said colour vector is displayed as a graph having three lines, one for each of red, green and blue colour components, said graph having a first axis indicative of colour vector and a second axis of luminance.

10. Apparatus for processing image data comprising storage means storing instructions, memory means for storing said instructions

during execution and image data, processing means for performing image processing in which said image data may processed to modify colour values, and monitor means for facilitating user interaction with said image processing, wherein

said processing means is configured such that, in response to said instructions, said image data is processed by a first step of:

initialising a colour vector function, in which colour vector is a function of luminance;

and then repeated steps of:

identifying a colour vector and a luminance range for said colour vector;

updating said colour vector function with said identification;

processing source image data to identify luminance values;

modifying source image colour in response to said identified source luminance values with reference to said colour vector function; and

previewing said modified source image.

11. A method of processing image data in an image processing system including memory means for storing instructions and image data, processing means for performing image processing in which said image data is processed to modify colour values,

said instructions defining colour modifying operations to be performed by said processing means to process said image data, wherein said operations include:

identifying a colour vector and a luminance range for said colour vector;

defining a colour vector function in response to said identification, in

which colour vector is a function of luminance;

processing source image data to identify luminance values; and

modifying colours in response to said luminance values with reference to said colour vector function.

12. A method according to claim **11**, wherein said colour vector function is defined by points on curves.

13. A method according to claim **11**, wherein said colour vector function is animated.

14. A method according to claim **11**, wherein said colour vector function is defined by applying said identified colour vector to a previously defined colour vector function.

15. A method according to claim **11**, wherein said colour vector function is expressed as a look up table addressable by luminance values of image colour data.

~~**16.** A method according to claim **11**, wherein said colour vector~~ function defines red, green and blue displacements with reference to barycentric co-ordinates.

17. A method according to claim **11**, wherein a user performs operations to control said image processing with reference to a graphical user interface presented on a monitor, said interface including a plurality of widgets for facilitating user communication with said processes for

modifying colour values.

18. A method according to claim **17**, wherein said identification of a colour vector is performed with reference to a user input of co-ordinates from a two-dimensional trackball widget, in which the dimensions controllable from said trackball are dimensions of pure colour.

19. A method according to claim **17**, wherein said colour vector is displayed as a graph having three lines, one for each of red, green and blue colour components, said graph having a first axis indicative of colour vector and a second axis of luminance.

20. A method of processing image data in an image processing system including memory means for storing instructions and image data, processing means for performing image processing in which said image data is processed to modify colour values,

said instructions defining colour modifying operations to be performed by said processing means to process said image data, wherein said operations include a first step of:

initialising a colour vector function, in which colour vector is a function of luminance;

and then repeated steps of:

identifying a colour vector and a luminance range for said colour vector;

updating said colour vector function with said identification;

processing source image data to identify luminance values;

modifying source image colour in response to said identified source

luminance values with reference to said colour vector function; and

previewing said modified source image.

21. A computer-readable medium having computer-readable instructions executable by a computer configurable for image processing, said computer including memory means for storing said instructions and image data, processing means for performing image processing in which said image data is processed to modify colour values,

said instructions defining operations to be performed by said processing means to process said image data, wherein said operations include:

identifying a colour vector and a luminance range for said colour vector;

defining a colour vector function in response to said identification, in which colour vector is a function of luminance;

processing source image data to identify luminance values; and

modifying colours in response to said luminance values with reference to said colour vector function.

22. A computer-readable medium according to claim **21**, wherein said colour vector function is defined by points on curves.

23. A computer-readable medium according to claim **21**, wherein said colour vector function is animated.

24. A computer-readable medium according to claim **21**, wherein said colour vector function is defined by applying said identified colour

vector to a previously defined colour vector function.

25. A computer-readable medium according to claim **21**, wherein said colour vector function is expressed as a look up table addressable by luminance values of image colour data.

26. A computer-readable medium according to claim **21**, wherein said colour vector function defines red, green and blue displacements with reference to barycentric co-ordinates.

27. A computer-readable medium according to claim **21**, wherein a user performs operations to control said image processing with reference to a graphical user interface presented on a monitor, said interface including a plurality of widgets for facilitating user communication with said processes for modifying colour values.

28. A computer-readable medium according to claim **27**, wherein said identification of a colour vector is performed with reference to a user input of co-ordinates from a two-dimensional trackball widget, in which the dimensions controllable from said trackball are dimensions of pure colour.

29. A computer-readable medium according to claim **27**, wherein said colour vector is displayed as a graph having three lines, one for each of red, green and blue colour components, said graph having a first axis indicative of colour vector and a second axis of luminance.

30. A computer-readable medium having computer-readable

instructions executable by a computer configurable for image processing, said computer including memory means for storing said instructions and image data, processing means for performing image processing in which said image data is processed to modify colour values,

said instructions defining operations to be performed by said processing means to process said image data, wherein said operations include a first step of:

initialising a colour vector function, in which colour vector is a function of luminance;

and then repeated steps of:

identifying a colour vector and a luminance range for said colour vector;

updating said colour vector function with said identification;

processing source image data to identify luminance values;

modifying source image colour in response to said identified source luminance values with reference to said colour vector function; and

previewing said modified source image.

Abstract

A method of modifying image data in which image colours are to be modified, including a first step of initialising a colour vector function, in which colour vector is a function of luminance, and then the following repeated steps. A user defines a luminance range (**616**, **617**) and a colour vector (**620**) for that range. The colour vector function is updated (**601**) and a look-up table (**407**) is generated (**602**) that is addressable by luminance. Image data (**405**) is processed by calculating each pixel's luminance and using this to address the red, green and blue values in the look-up table (**407**). The red, green and blue values so obtained are then added to each pixel's original red, green and blue values, resulting in output image pixels.

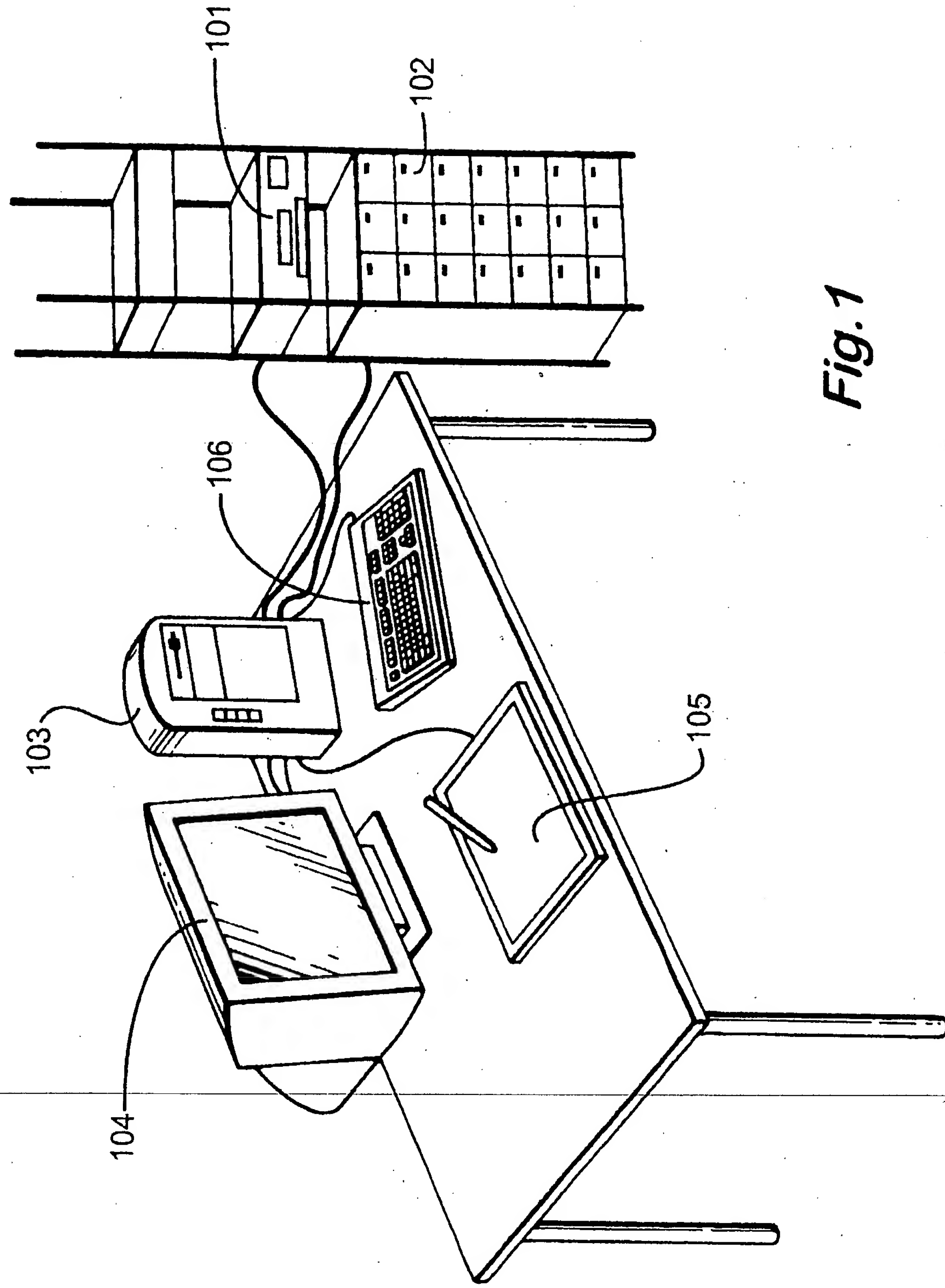


Fig.1

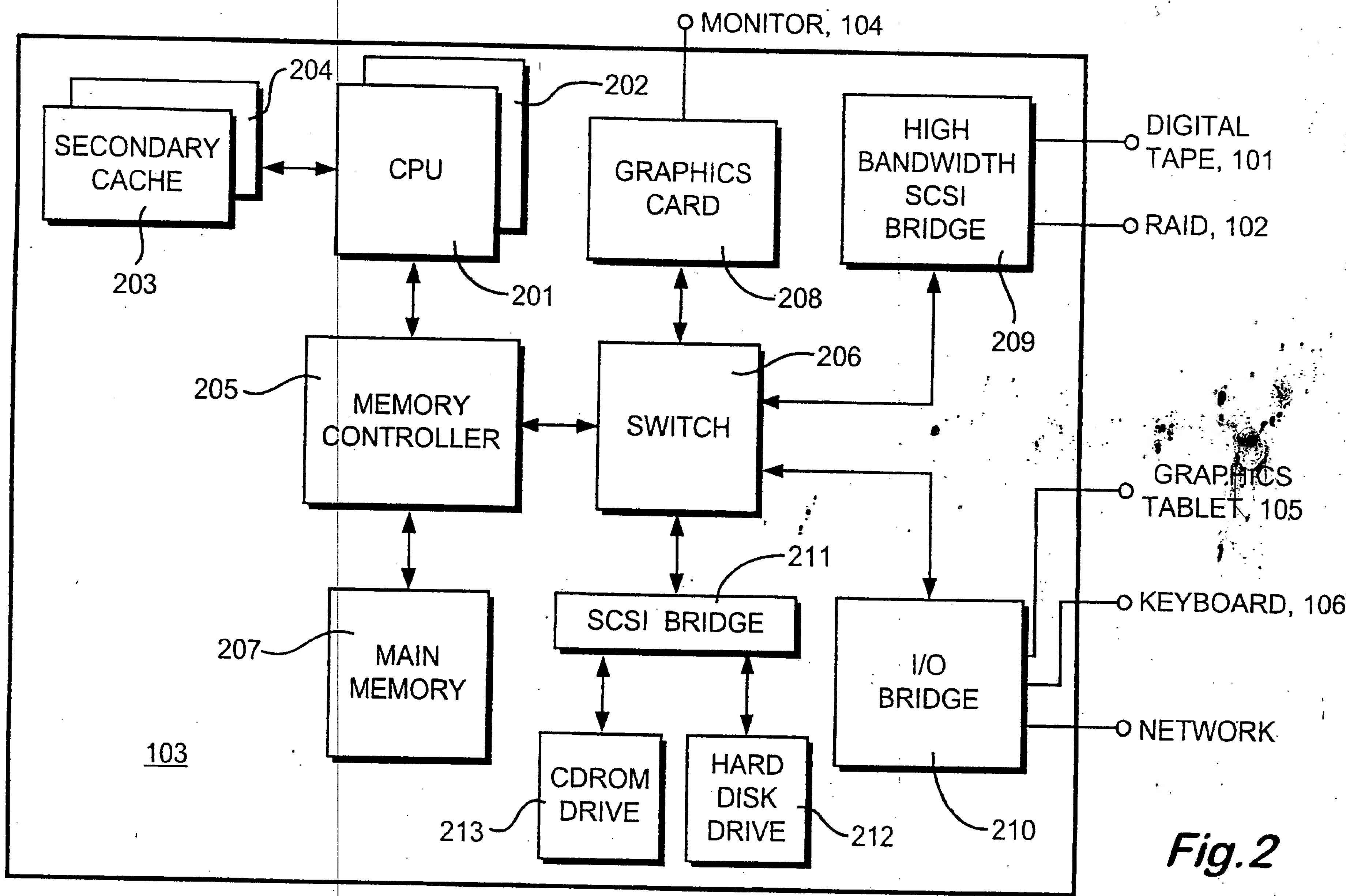

MONITOR, 104
204
202
SECONDARY CACHE
CPU
GRAPHICS CARD
HIGH BANDWIDTH SCSI BRIDGE
DIGITAL TAPE, 101
RAID, 102
203
201
208
209
205
MEMORY CONTROLLER
SWITCH
206
GRAPHICS TABLET, 105
211
207
MAIN MEMORY
SCSI BRIDGE
I/O BRIDGE
KEYBOARD, 106
NETWORK
103
CDROM DRIVE
HARD DISK DRIVE
213
212
210

Fig.2

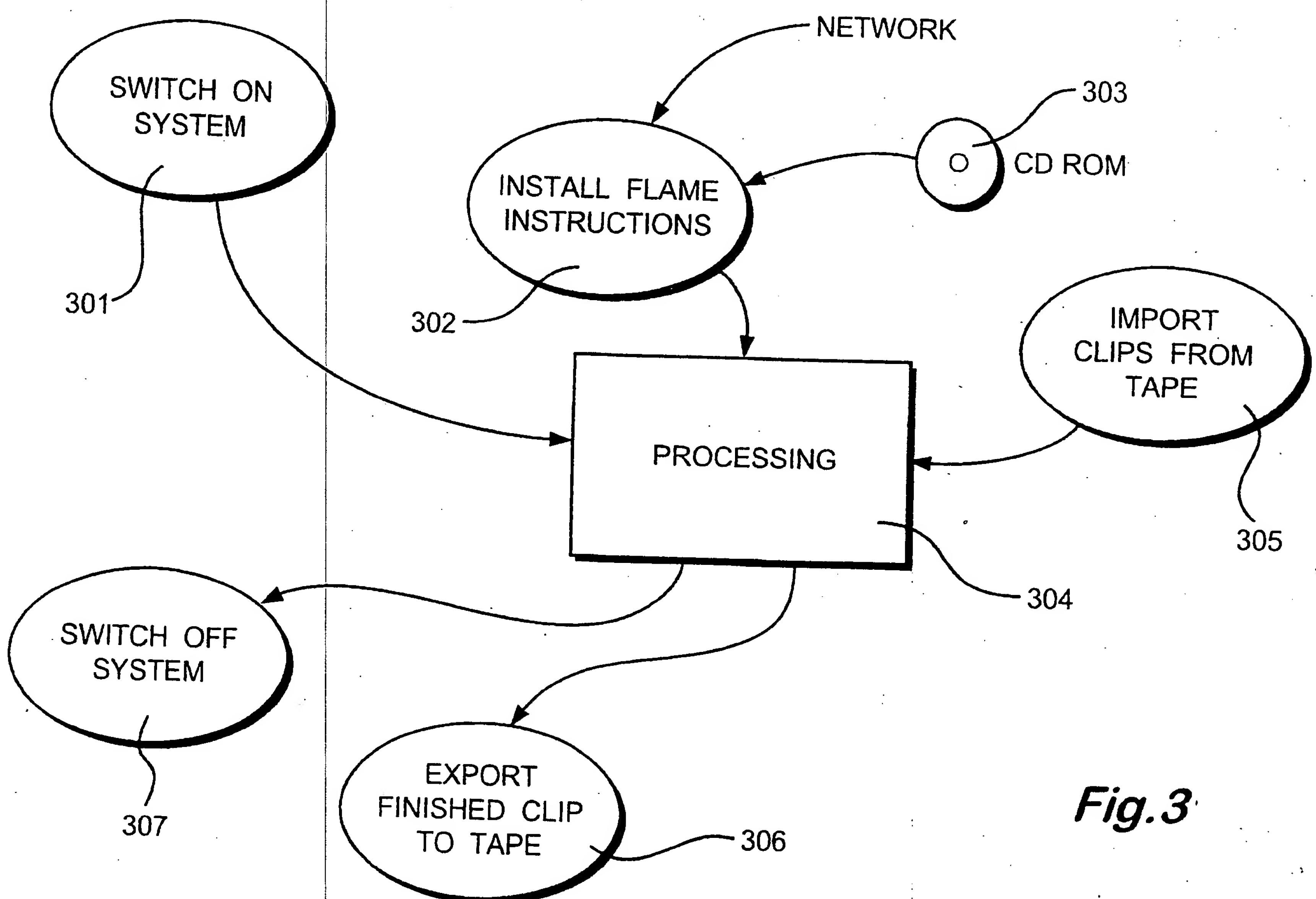
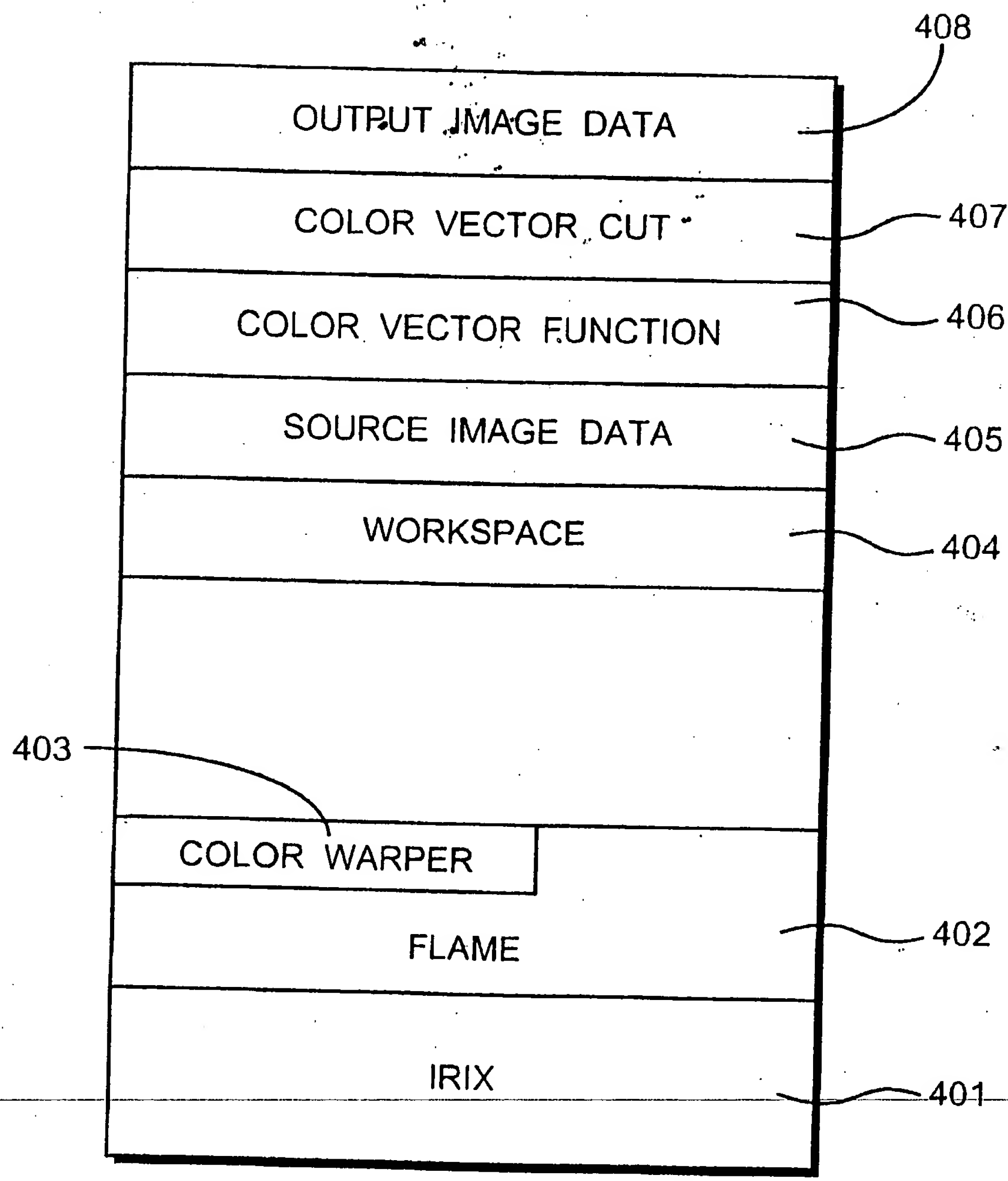

SWITCH ON SYSTEM
301
NETWORK
303
CD ROM
INSTALL FLAME INSTRUCTIONS
302
IMPORT CLIPS FROM TAPE
PROCESSING
305
304
SWITCH OFF SYSTEM
307
EXPORT FINISHED CLIP TO TAPE
306

Fig.3



408
OUTPUT IMAGE DATA
COLOR VECTOR CUT
407
COLOR VECTOR FUNCTION
406
SOURCE IMAGE DATA
405
WORKSPACE
404
403
COLOR WARPER
FLAME
402
IRIX
401

Fig.4

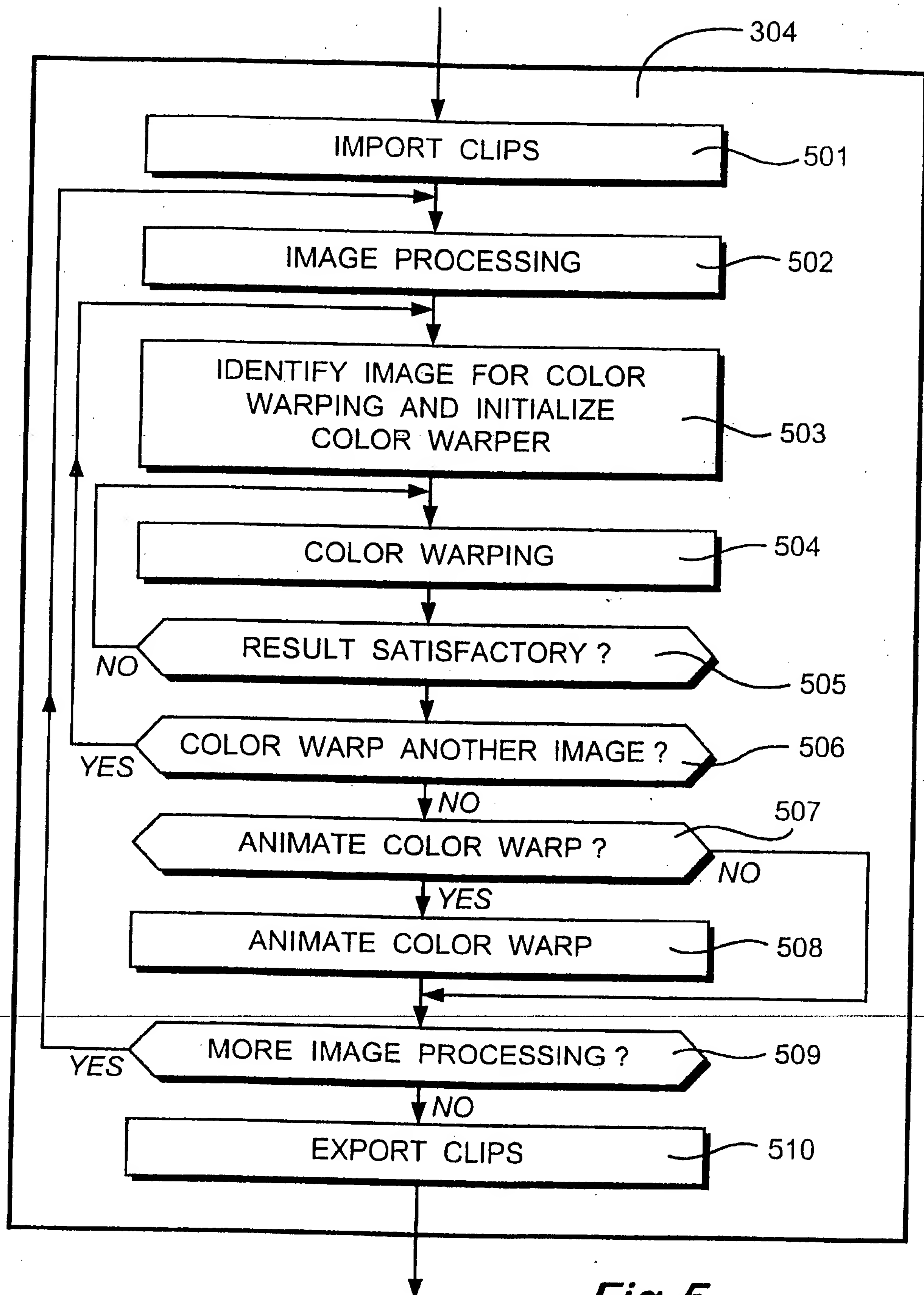

304
IMPORT CLIPS
501
IMAGE PROCESSING
502
IDENTIFY IMAGE FOR COLOR WARPING AND INITIALIZE COLOR WARPER
503
COLOR WARPING
504
RESULT SATISFACTORY ?
NO
505
COLOR WARP ANOTHER IMAGE ?
YES
506
NO
ANIMATE COLOR WARP ?
507
NO
YES
ANIMATE COLOR WARP
508
MORE IMAGE PROCESSING ?
YES
509
NO
EXPORT CLIPS
510

Fig.5

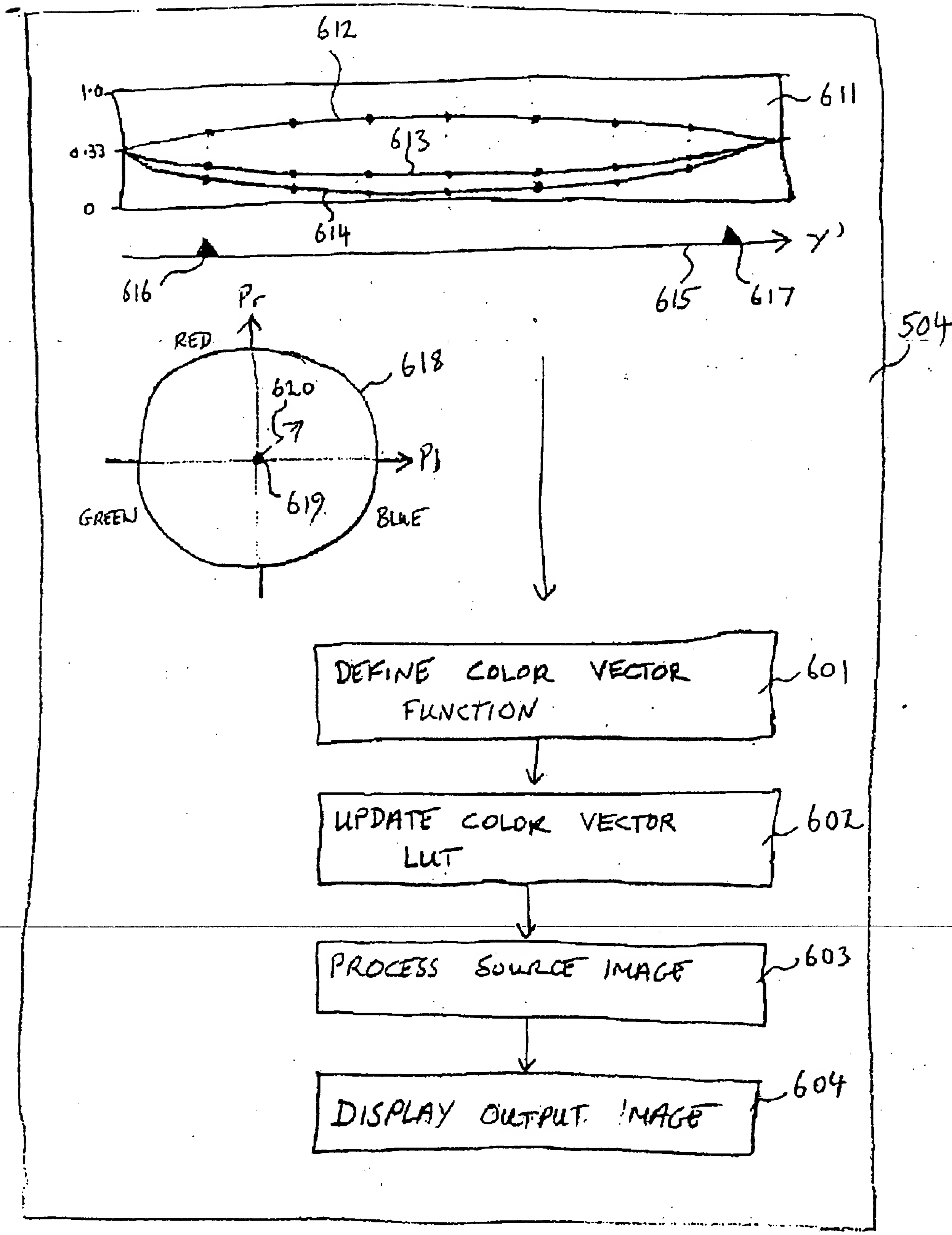

612
1.0
0.33
0
611
613
614
y'
616
615
617
504
Pr
RED
618
620
Pb
GREEN
619
BLUE
DEFINE COLOR VECTOR FUNCTION
601
UPDATE COLOR VECTOR LUT
602
PROCESS SOURCE IMAGE
603
DISPLAY OUTPUT IMAGE
604

Figure 6

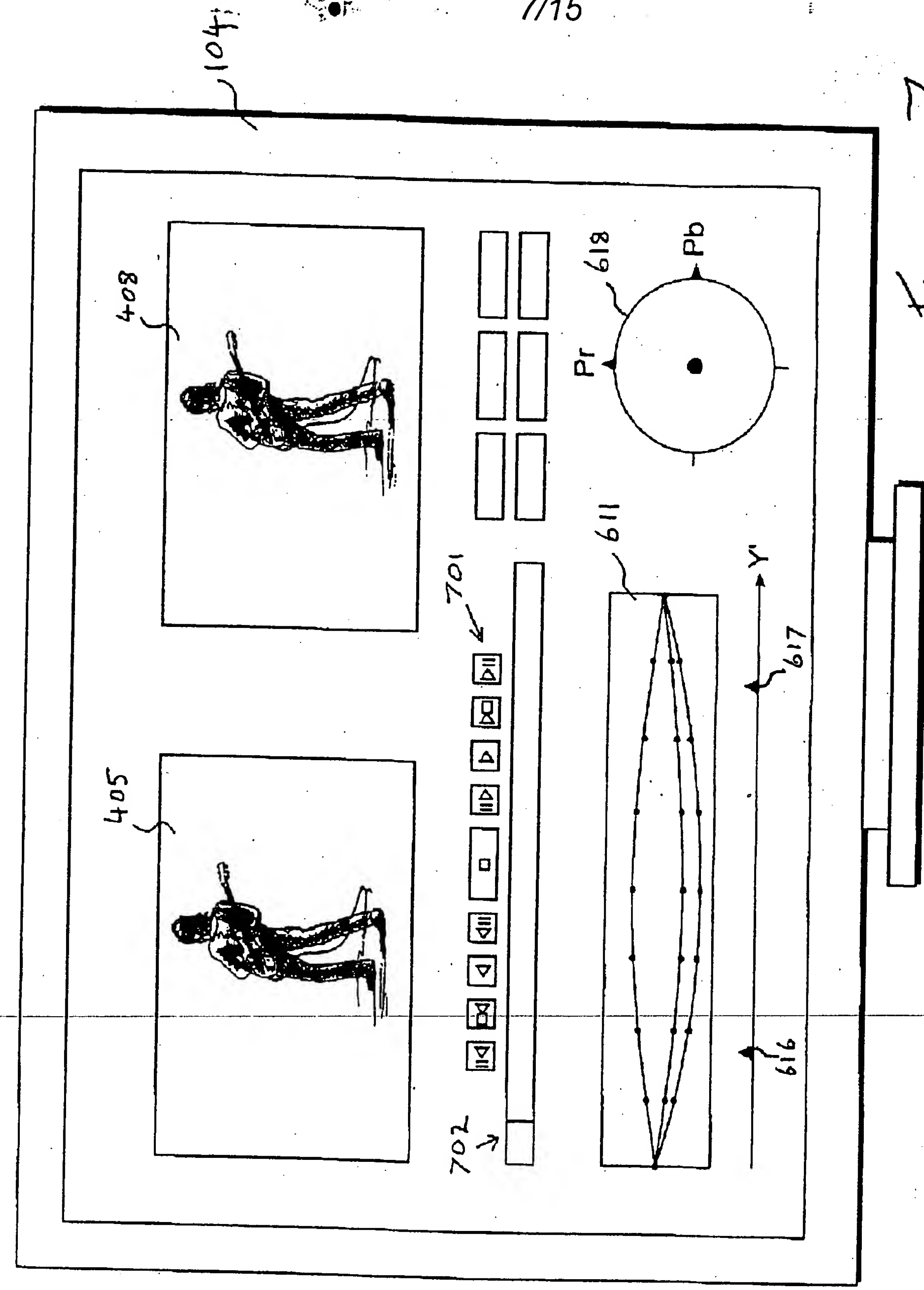


Figure 7

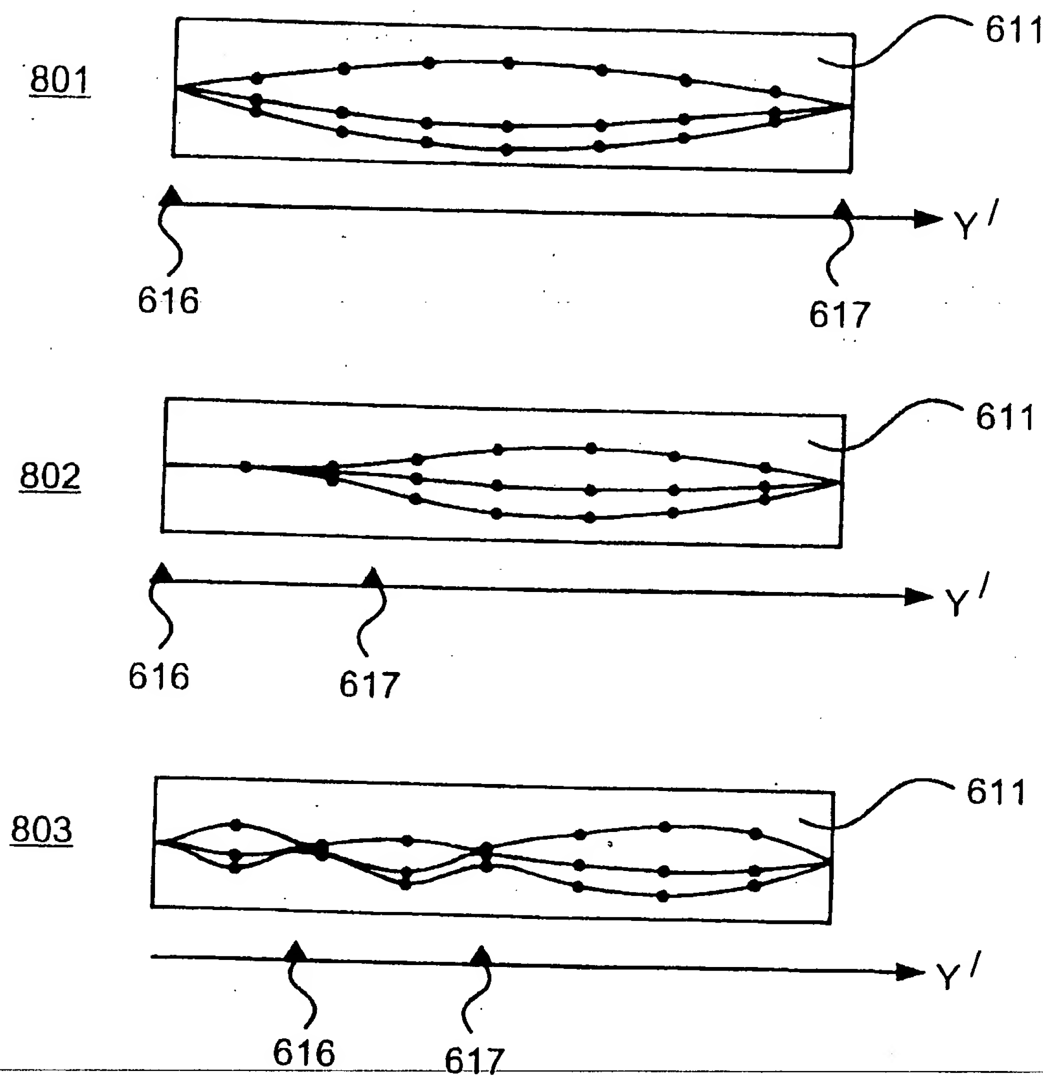


Fig.8

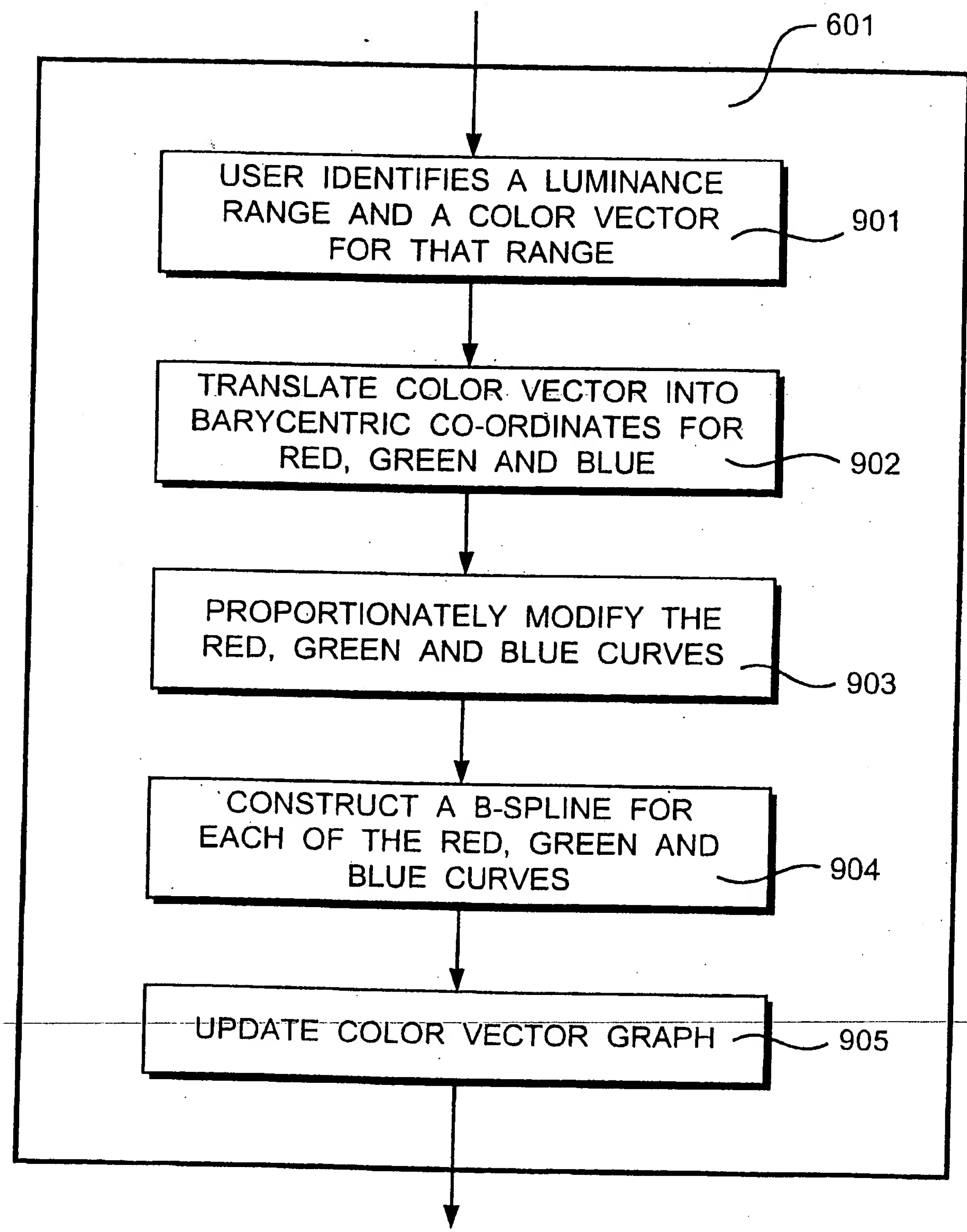

601
USER IDENTIFIES A LUMINANCE RANGE AND A COLOR VECTOR FOR THAT RANGE
901
TRANSLATE COLOR VECTOR INTO BARYCENTRIC CO-ORDINATES FOR RED, GREEN AND BLUE
902
PROPORTIONATELY MODIFY THE RED, GREEN AND BLUE CURVES
903
CONSTRUCT A B-SPLINE FOR EACH OF THE RED, GREEN AND BLUE CURVES
904
UPDATE COLOR VECTOR GRAPH
905

Fig.9

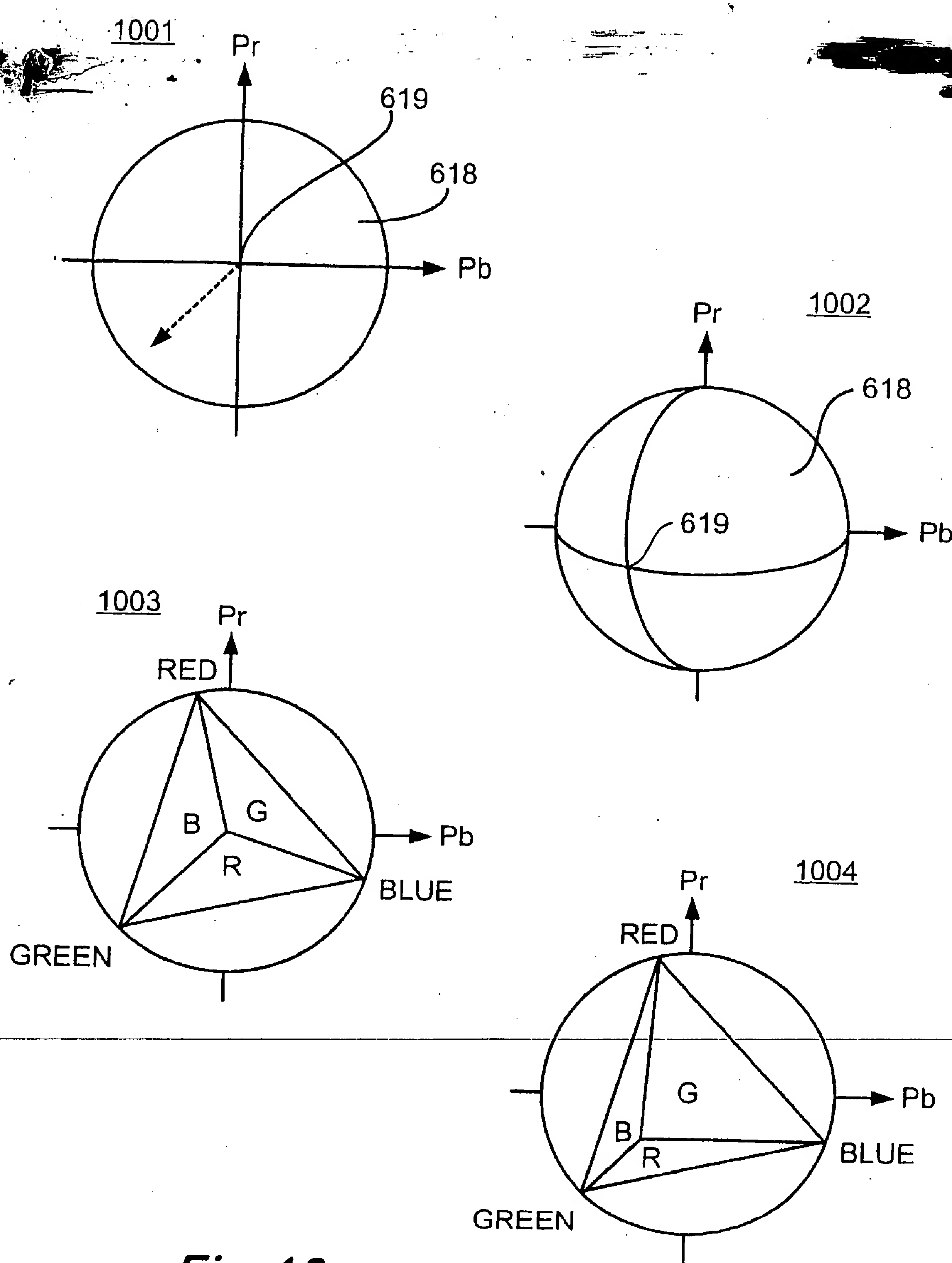

1001
Pr
619
618
Pb
1002
Pr
618
619
Pb
1003
Pr
RED
B
G
R
Pb
BLUE
GREEN
1004
Pr
RED
G
B
R
Pb
BLUE
GREEN

Fig. 10

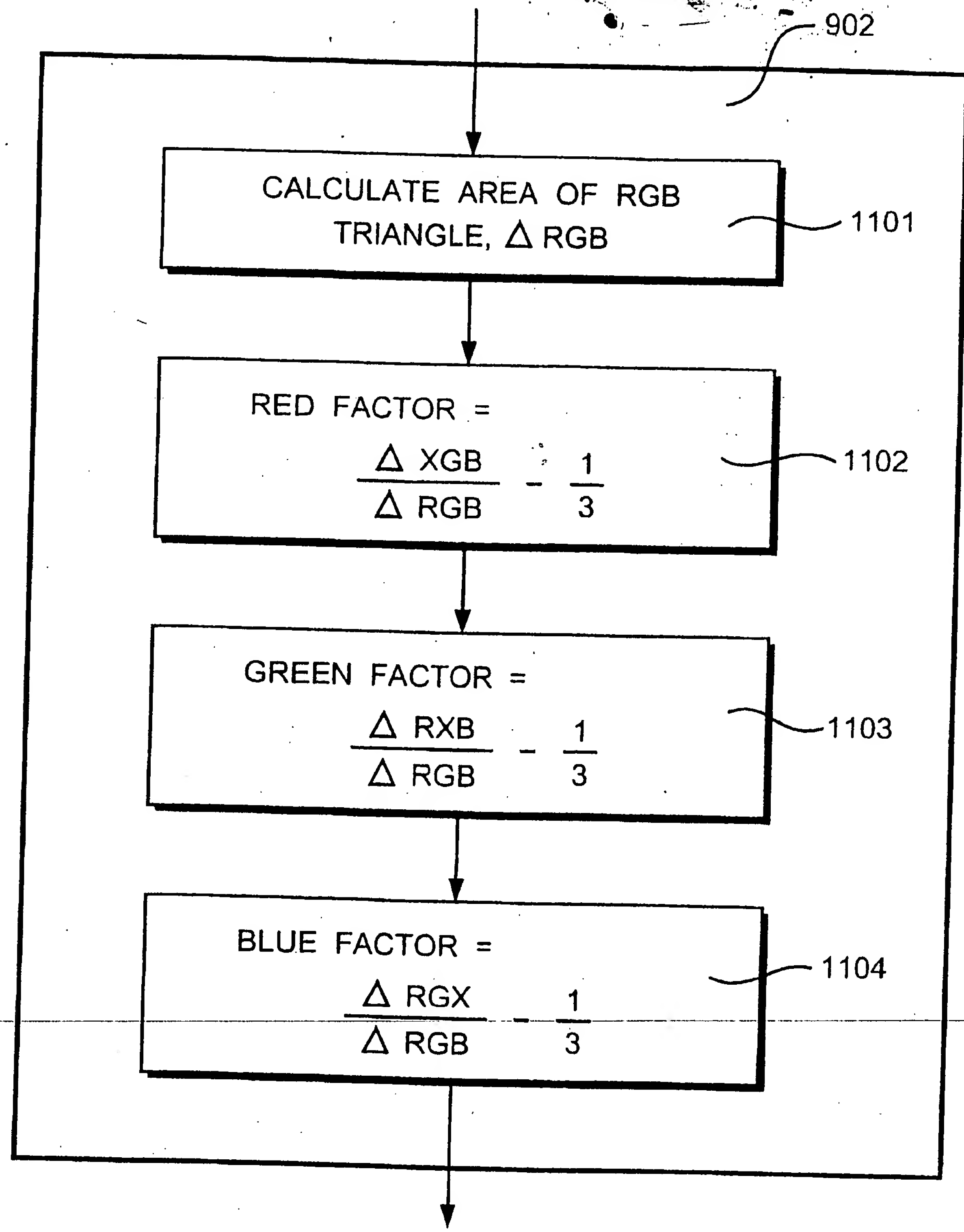

902
CALCULATE AREA OF RGB TRIANGLE, Δ RGB
1101
RED FACTOR =
Δ XGB / Δ RGB − 1/3
1102
GREEN FACTOR =
Δ RXB / Δ RGB − 1/3
1103
BLUE FACTOR =
Δ RGX / Δ RGB − 1/3
1104

Fig. 11

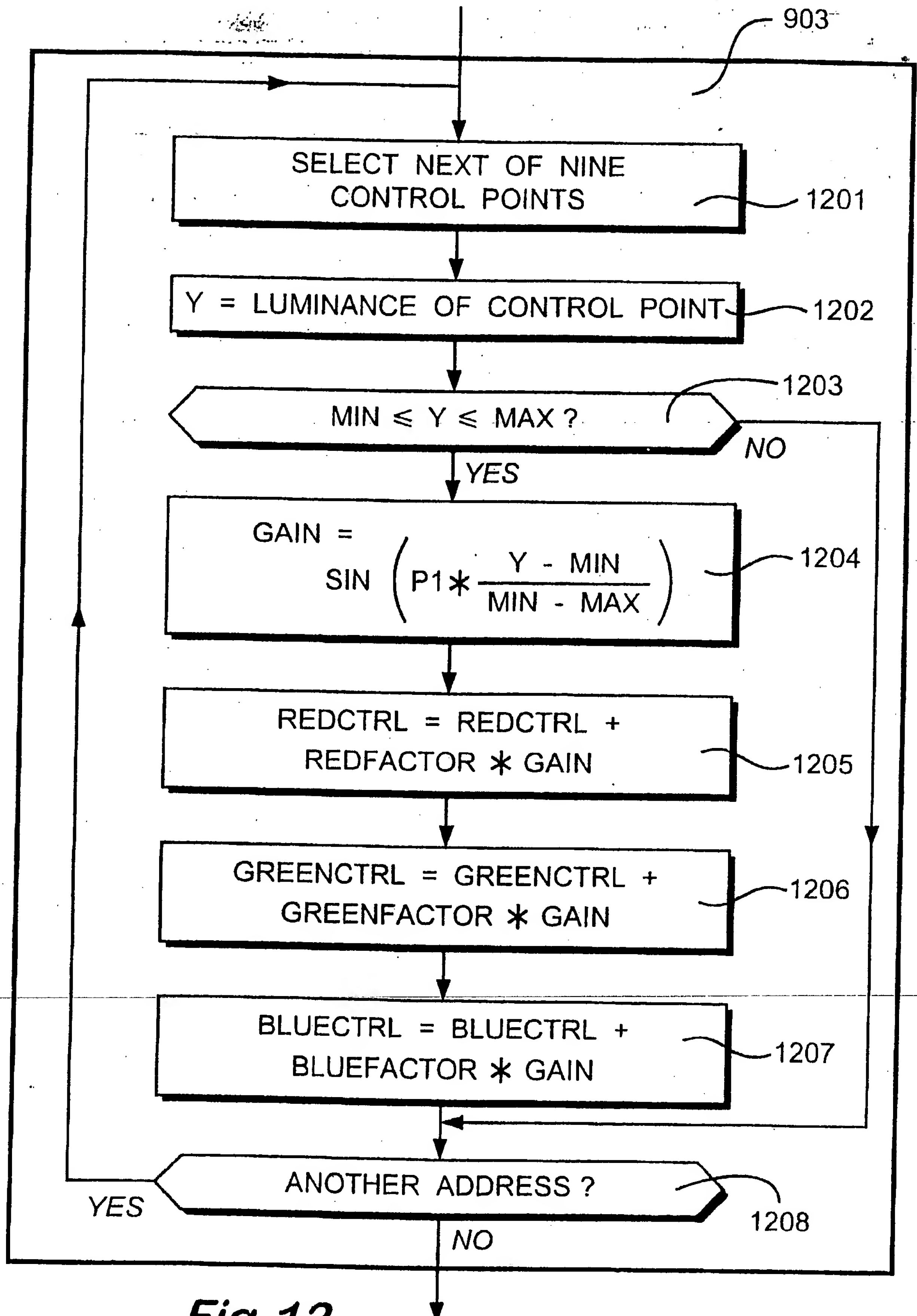

903
SELECT NEXT OF NINE CONTROL POINTS
1201
Y = LUMINANCE OF CONTROL POINT
1202
1203
MIN ≤ Y ≤ MAX ?
NO
YES
GAIN =
SIN (P1 ∗ (Y - MIN)/(MIN - MAX))
1204
REDCTRL = REDCTRL + REDFACTOR ∗ GAIN
1205
GREENCTRL = GREENCTRL + GREENFACTOR ∗ GAIN
1206
BLUECTRL = BLUECTRL + BLUEFACTOR ∗ GAIN
1207
ANOTHER ADDRESS ?
YES
1208
NO

Fig. 12

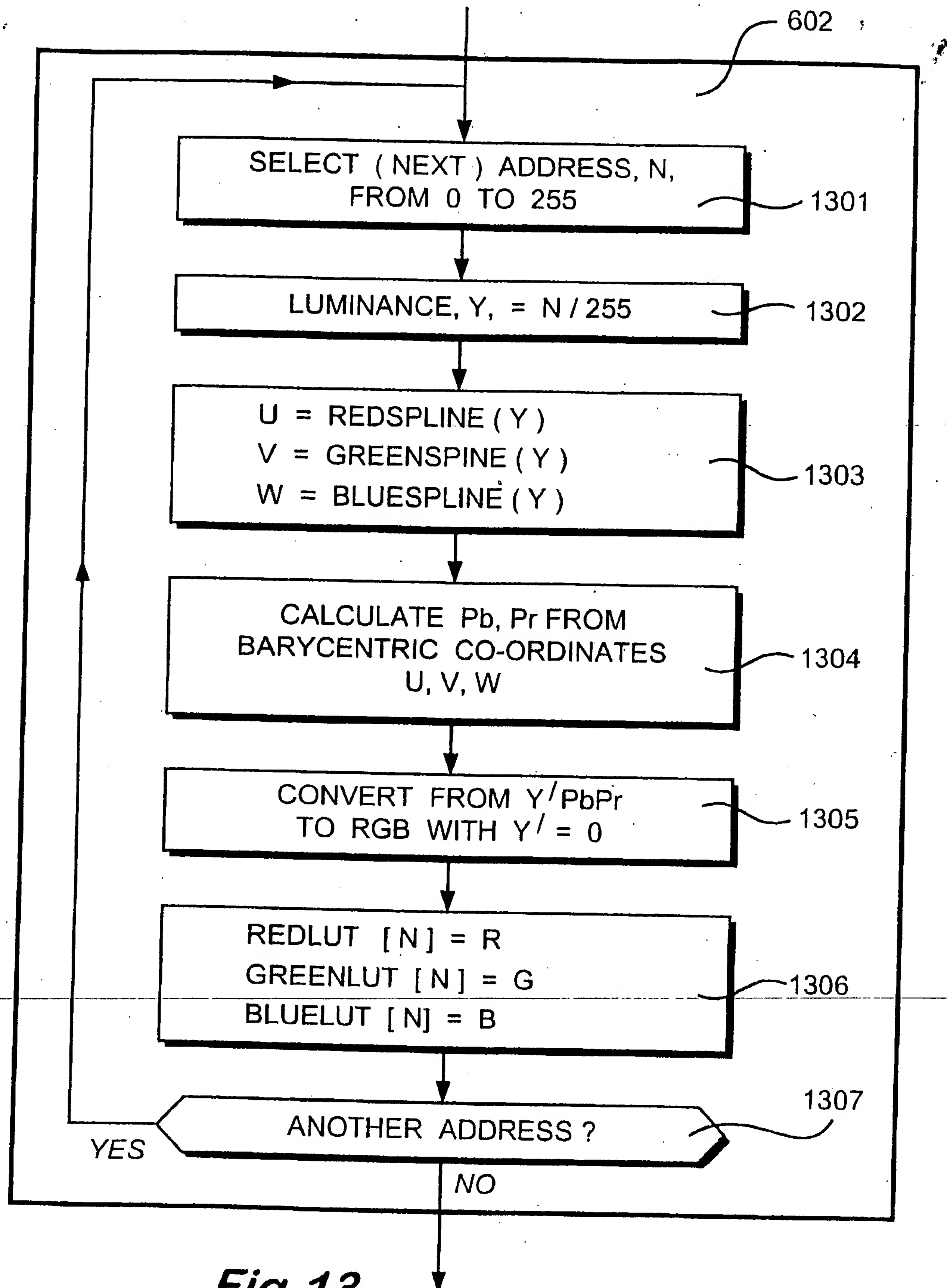
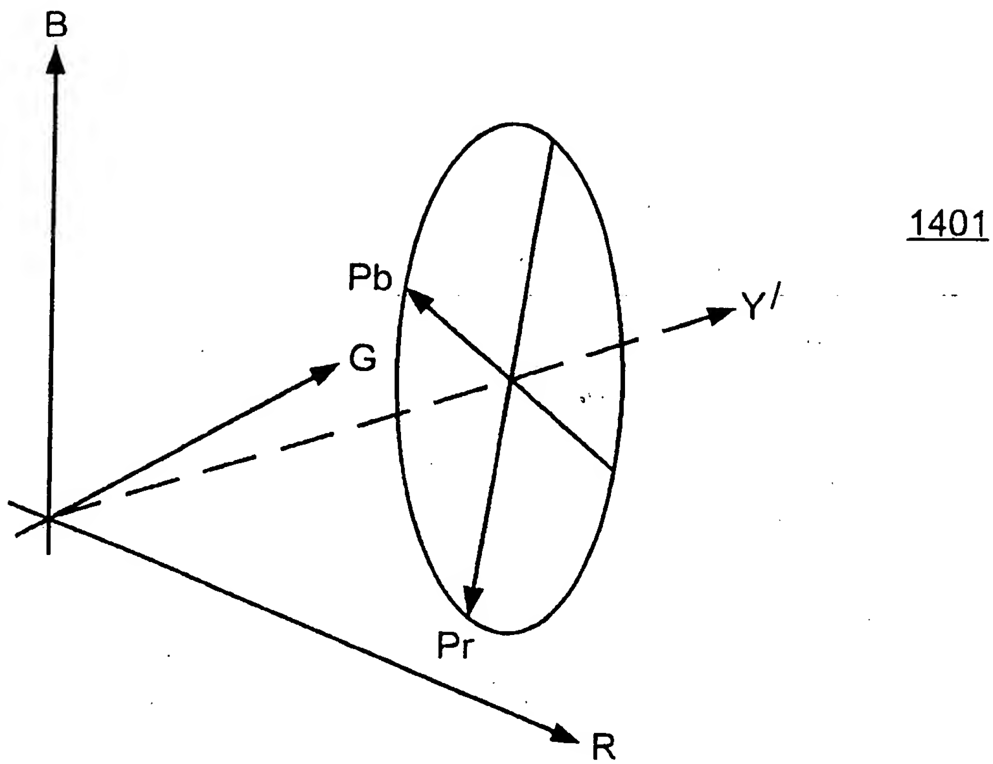

602
SELECT (NEXT) ADDRESS, N, FROM 0 TO 255
1301
LUMINANCE, Y, = N / 255
1302
U = REDSPLINE (Y)
V = GREENSPINE (Y)
W = BLUESPLINE (Y)
1303
CALCULATE Pb, Pr FROM BARYCENTRIC CO-ORDINATES U, V, W
1304
CONVERT FROM Y/PbPr TO RGB WITH Y/ = 0
1305
REDLUT [N] = R
GREENLUT [N] = G
BLUELUT [N] = B
1306
1307
ANOTHER ADDRESS ?
YES
NO

Fig. 13



$$Y' = 0.299N\,R + 0.587\,G + 0.114\,B$$
$$Pb = -0.169\,R - 0.331\,G + 0.5\,B$$
$$Pr = 0.5\,R - 0.419\,G - 0.081\,B$$

1402

MATRIX 'A' TRANSFORMS RGB TO Y/ Pb Pr

MATRIX 'A^{-1}' TRANSFORMS Y/ Pb Pr TO RGB

RGB BLACK = (0, 0, 0); Y/ Pb Pr BLACK = (0, 0, 0)
RGB WHITE = (1, 1, 1); Y/ Pb Pr WHITE = (1, 0, 0)

Fig. 14

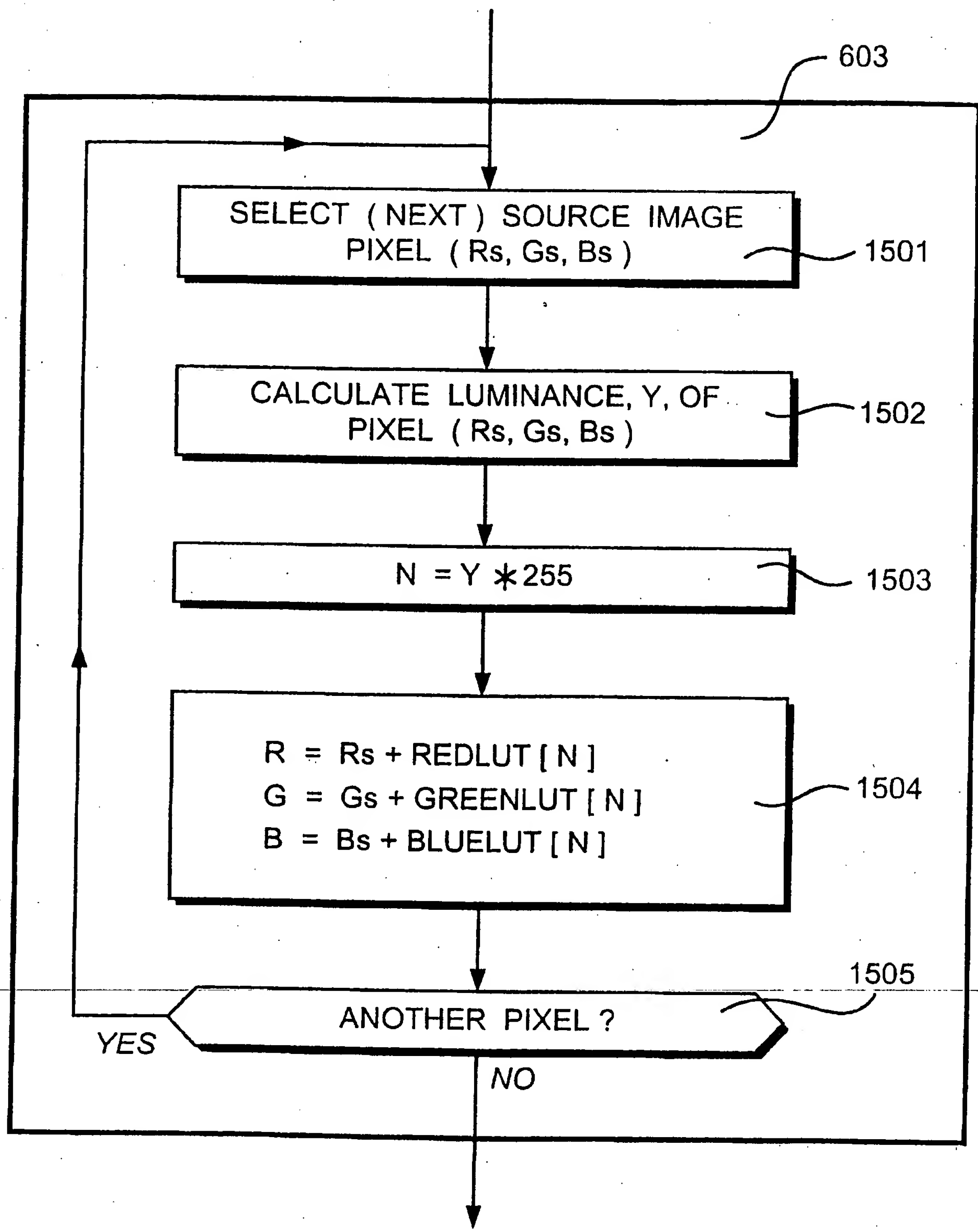

603
SELECT (NEXT) SOURCE IMAGE PIXEL (Rs, Gs, Bs)
1501
CALCULATE LUMINANCE, Y, OF PIXEL (Rs, Gs, Bs)
1502
N = Y * 255
1503
R = Rs + REDLUT [N]
G = Gs + GREENLUT [N]
B = Bs + BLUELUT [N]
1504
1505
ANOTHER PIXEL ?
YES
NO

Fig. 15